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Objectively measured sedentary time and academic achievement in schoolchildren

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ABSTRACT

This study aimed to evaluate the relationship between objectively measured total sedentary time and academic achievement (AA) in Portuguese children. The sample comprised of 213 children (51.6% girls) aged 9.46 ± 0.43 years, from the north of Portugal. Sedentary time was measured with accelerometry, and AA was assessed using the Portuguese Language and Mathematics *National Exams* results. Multilevel linear regression models were fitted to assess regression coefficients predicting AA. The results showed that objectively measured total sedentary time was not associated with AA, after adjusting for potential confounders.

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KEYWORDS

Sedentary behaviour; academic performance; physical activity; accelerometers; childhood

Introduction

Sedentary behaviour (SB) is defined as any waking behaviour characterised by an energy expenditure of ≤ 1.5 metabolic equivalent of task while in a sitting or reclining posture (Sedentary Behaviour Research Network, 2012). Accumulating evidence suggests that SB and physical activity are two independent constructs, since it has been demonstrated that they may operate through different behavioural mechanisms (Owen, Leslie, Salmon, & Fotheringham, 2000), have different determinants (Gordon-Larsen, McMurray, & Popkin, 2000), track differently (Gordon-Larsen, Nelson, & Popkin, 2004) and have a distinct range of potential health consequences (Tremblay, Esliger, Tremblay, & Colley, 2007).

In developed countries, children and adults spend a large portion of their days in sedentary pursuits (Baptista et al., 2012; Matthews et al., 2008). In adults, SB was found to be associated with increased risk of cardio-metabolic disease, all-cause mortality and a variety of negative physiological and psychological outcomes (de Rezende, Rodrigues Lopes, Rey-Lopez, Matsudo, & Luiz Odo, 2014; Katzmarzyk, 2010; Katzmarzyk, Church, Craig, & Bouchard, 2009; Tremblay, Colley, Saunders, Healy, & Owen, 2010; Tremblay et al., 2011).

In school-aged children, SB (mostly assessed through the amount of time spent viewing television) has been associated with unfavourable body composition, decreased fitness, lower self-esteem and pro-social behaviour and decreased academic achievement (AA) (Tremblay et al., 2011). Therefore, SB may result not only in poor physical health but also in poor cognitive health (Bradley & Greene, 2013). Studies conducted with children and adolescents have suggested a negative effect of television viewing and screen time on school performance (Borzekowski & Robinson, 2005; Hancox, Milne, & Poulton,

2005; Schmidt & Vandewater, 2008; Sharif & Sargent, 2006; Sharif, Wills, & Sargent, 2010; Shin, 2004; Zimmerman & Christakis, 2005). Children with higher levels of television viewing and screen time tended to have a lower rate of homework completion (Shin, 2004), spend less time studying and reading (Wiecha, Sobol, Peterson, & Gortmaker, 2001), experience greater difficulties in focusing and attention (Johnson, Cohen, Kasen, & Brook, 2007), have more learning problems (Ozmert, Toyran, & Yurdakok, 2002) and demonstrate lower AA (Jaruratanasirikul, Wongwaitawee Wong, & Sangsupawanich, 2009; Kristjansson, Sigfusdottir, Allegrante, & Helgason, 2009; Sharif & Sargent, 2006; Sharif et al., 2010). By contrast, higher levels of physical activity (amounts and/or intensities in sustained bouts or short bursts) have been positively associated with higher AA (Burkhalter & Hillman, 2011; Hillman, Erickson, & Kramer, 2008; Langford et al., 2014; Ruiz et al., 2010; Trudeau & Shephard, 2008).

Despite that the majority of the studies show a detrimental relationship between SB and AA, most studies have relied on self-reported leisure time SBs, such as TV viewing, computer use, videogames or overall screen time (Tremblay et al., 2011). However, while these activities may represent a substantial portion of the amount of time spent in total SB, they do not represent the total amount of everyday sedentary time. Moreover, objectively measuring total sedentary time with devices such as accelerometers may offer particular advantages, as these devices do not rely on subjects' recall and may capture the entire daily pattern of both physical activity and sedentary time. In addition, most studies fail to control their analysis for important confounding variables such as body composition, physical activity and socio-economic status (Lawlor et al., 2006; Trudeau & Shephard, 2008).

To the best of our knowledge, in the literature, there are very few studies analysing the associations between objectively measured sedentary time and AA (Esteban-Cornejo et al., 2015; Syvaaja et al., 2013). The aim of this study was to evaluate the relationship between objectively measured sedentary time and direct and objective indicators of AA in Portuguese children aged 9 and 10 years, accounting for several important confounders.

Methods

Data for the present study derived from the Bracara Study aimed to evaluate the relations between motor coordination, physical activity, SB, physical fitness, body composition, AA and health behaviours among elementary school children. The Bracara Study was conducted in a middle city located in the north of Portugal during 2009/2010. Study design, sampling and measures were reported elsewhere (Lopes, Santos, Pereira, & Lopes, 2012). Briefly, the final sample of Bracara Study accounts for 596 participants from 13 urban public elementary schools; due to temporal and material restrictions (accelerometers available) 383 children did not wear the accelerometer. However, drop-out analysis showed that the 383 missing children had similar mean values for height, weight and socio-economic status (data not shown). Therefore, this study included 213 participants (51.6% girls) aged 9.46 ± 0.43 years.

All ethical and legal procedures for this study were obtained from the Ethics Committee of the Institute of Education, University of Minho (Department of Theoretical Education and Artistic and Physical Education). Parents or legal guardians signed an informed written consent.

Measures

Anthropometry

Weight was measured to the nearest 0.1 kg using a regularly calibrated digital scale (Tanita TBF-300) while the child was wearing light clothing without shoes. Height was measured to the nearest millimetre with a field stadiometer (Seca 220). Body mass index (body mass (kg)/height (m^2)) was calculated.

Sedentary time and physical activity

Sedentary time and physical activity were assessed with accelerometer (GT1 M Actigraph, Pensacola, FL, USA) over 5 consecutive days (three week days and two weekend days). The accelerometer was attached tightly in the hip, on the right side, with the notch faced upwards, and participants were instructed to use the accelerometer during waking hours and remove it during water-based activities, according to established procedures (Ward, Evenson, Vaughn, Rodgers, & Troiano, 2005). The epoch length was set to 15 s to allow a more detailed estimate of physical activity intensity (Ward et al., 2005).

Accelerometer data were analysed by an automated data reduction programme (MAHUFFe; see www.mrc-epid.cam.ac.uk). Periods with 60 min of consecutive zeros were detected and flagged as times in which the monitor was not worn (Troiano et al., 2008). Participants had to have at least 10 h

of data to count as a valid day and to have at least 3 valid days to be included (two week days and one weekend day). The established accelerometer age-specific cut-points proposed by Freedson and published by Trost et al. (2002) were used to determine physical activity intensities. Sedentary time was identified using a cut-point of $<100 \text{ counts} \cdot \text{min}^{-1}$, as this cut-off was shown to have an excellent classification accuracy (Trost, Loprinzi, Moore, & Pfeiffer, 2010).

Cardiorespiratory fitness

The 20-m shuttle-run test was used to evaluate cardiorespiratory fitness. This test was conducted according to the Fitnessgram measurement procedures (Welk & Meredith, 2008) and is described elsewhere (Lopes, Santos, Pereira, & Lopes, 2013).

The number of shuttles performed was recorded. Age-adjusted and sex-adjusted z-scores were computed, because the age-specific and sex-specific cut-off points of the Fitnessgram criteria are only developed for children aged 10 years or older, and most participants in this study were 9 years old.

Motor coordination

Motor coordination was evaluated with the body coordination test, Körperkoordination Test für Kinder (KTK), developed by Kiphard and Schilling (1974). The KTK battery has four items: balance, jumping laterally, hopping on one leg over an obstacle and shifting platforms. The tests were applied following the original protocols as described elsewhere (Lopes et al., 2013).

Academic achievement

AA was assessed using the Portuguese Language and Mathematics *National Exams* which are mandatory for all fourth grade students. The exams were administered in May 2009 by two supervision teachers in the classroom. The Educational Evaluation Office from the Portuguese Ministry of Education performs management, analysis and maintenance of student data and the National Exams database. The National Exams are criterion-referenced tests that provide scores to students, teachers and parents according to the performance levels: A (very good), B (good), C (fair), D and E (insufficient). The exams aim to evaluate how primary competences are appropriated by students in order to diagnose and evaluate the educational system function. For each exam, 1, 2, 3, 4 and 5 points were attributed to scores of E, D, C, B and A, respectively. An AA score was computed by summing the points attained for each of the exams.

Sociodemographics

Each child's date of birth, gender and family income were extracted from the schools' administrative record systems. The school's socio-economic status used by the Portuguese Ministry of Education is based on annual family income: eligible for benefit A, eligible for benefit B or not eligible, and was used as a proxy measurement of family socio-economic status (Education, 2009). According to the Portuguese Ministry of Education, those eligible for benefit A receive books, school

supplies and meals for free; those eligible for benefit B receive 50% of the books required and a 50% discount on meals.

Mother's educational level was assessed by questionnaire and categorised according to the Portuguese Education Level: Low (mandatory education – 9 school years), Medium (secondary education – 12 school years) and High (college or university degree).

Statistical analysis

Descriptive data are presented as means and standard deviations and percentages. AA score was normalised by natural logarithm transformation. Two-sided *t*-tests and chi-square tests were performed to assess gender differences for continuous and categorical variables, respectively. To analyse the relationship between sedentary time and the AA score (mean min/day), a series of multilevel linear regression models was fitted to assess rate ratios predicting AA. Subjects were nested in three levels: level 1 – subject, level 2 – teacher and level 3 – school. In the construction of the multilevel regression models, we started by investigating intra-class coefficients (ICCs) from the unconditional means model to estimate the proportion of the total variance of the AA score attributable to teacher and school differences. In our data, the ICC for teacher was 0.00001 and for school was 0.061, which means that the variation of the AA score due to the teachers' influence is virtually zero and that the variation of this score attributed to the school is 6.1%. Therefore, a series of linear multilevel regression models were constructed with two levels (student and school). Model 1 (the "crude model") was adjusted for accelerometer wear time; model 2 was additionally adjusted for age, gender, family income, mother's educational level and body mass index; model 3 included all the variables of model 2 and moderate-to-vigorous physical activity (MVPA); model 4 included all the variables of model 2 and cardiorespiratory fitness; model 5 included all the variables of model 2 and motor coordination.

Data were analysed using the IBM SPSS Statistics v.19 (SPSS, Inc. IBM Company, USA) and MLWin (University of Bristol, UK). A *P*-value under 0.05 denoted statistical significance.

Results

The descriptive characteristics of the participants are shown in Table 1. Participants spent, on average, 75.6% of their waking time being sedentary. Boys spent less time on sedentary

activities (443.32 ± 34.42 mean min/day) than girls (463.17 ± 27.71 mean min/day), while girls were engaged in fewer minutes of MVPA (74.12 ± 19.30 mean min/day) than boys (91.35 ± 25.75 mean min/day) ($P < 0.001$ for all). No significant differences were found between genders regarding AA. For motor coordination and cardiorespiratory fitness, boys performed significantly better than girls ($P < 0.001$ for all).

None of the participants scored grade E (lowest level) in Portuguese Language and in Mathematics Exams. As presented in Table 2, no statistical gender differences were found in both Portuguese Language and Mathematics Exams.

As shown in Table 3, sedentary time was not associated with AA, although motor coordination was significantly associated with AA.

Discussion

The main finding of this study suggests that objectively measured total sedentary time was not associated with AA. This result is in line with the results of other studies as well (Esteban-Cornejo et al., 2015; Syvaioja et al., 2013).

It seems that different types of sedentary activities relate to AA differently. Indeed, recent studies found that sedentary activities related to academic or "educational" skills such as homework, reading and studying were positively associated with better AA (Esteban-Cornejo et al., 2015; Haapala et al., 2014), and that excessive computer use, TV time or overall screen time are negatively associated with AA (Johnson et al., 2007; Sharif & Sargent, 2006; Sharif et al., 2010; Syvaioja et al., 2013).

Table 2. Frequency of the academic achievement scores attained in the Portuguese Language and Mathematics Exams by gender.

Portuguese Language and Mathematics Exams by gender								
		All (<i>n</i> = 213)		Girls (<i>n</i> = 110)		Boys (<i>n</i> = 103)		Pgender ^a
		<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	
Portuguese Language Exam								
A		18	8.5	6	5.5	12	11.7	0.206
B		72	33.8	43	39.1	29	28.2	
C		88	41.3	43	39.1	45	43.7	
D		35	16.4	18	16.4	17	16.5	
Mathematics Exam								
A		16	7.5	6	5.5	10	9.7	0.404
B		65	30.5	38	34.5	27	26.2	
C		81	38	42	38.2	39	37.9	
D		51	23.9	24	21.8	27	26.2	

^aChi-square test for categorical variables.

Table 1. Participants' characteristics (means \pm standard deviation).

	All (<i>n</i> = 213) Mean \pm SD	Girls (<i>n</i> = 110) Mean \pm SD	Boys (<i>n</i> = 103) Mean \pm SD	Pgender ^a
Age (years)	9.46 \pm 0.43	9.45 \pm 0.37	9.48 \pm 0.50	0.612
Sedentary time (min/day) ^b	453.62 \pm 32.75	463.17 \pm 27.71	443.32 \pm 34.42	<0.001
Sedentary time (%) ^b	75.60 \pm 5.46	77.20 \pm 4.62	73.90 \pm 5.79	<0.001
Academic achievement (sum of scores)	5.44 \pm 1.58	5.43 \pm 1.47	5.46 \pm 1.69	0.893
MVPA (mean min/day) ^b	82.45 \pm 24.18	74.12 \pm 19.30	91.35 \pm 25.75	<0.001
CRF (number of laps)	21.46 \pm 11.61	16.91 \pm 7.37	26.33 \pm 13.26	<0.001
Motor coordination (motor quotient)	86.72 \pm 14.40	83.56 \pm 13.78	90.09 \pm 14.33	0.001
Body mass index (weight/height ²)	18.35 \pm 3.11	18.43 \pm 3.21	18.27 \pm 3.01	0.712

MVPA: moderate-to-vigorous physical activity; CRF: cardiorespiratory fitness.

^a*t*-Test to compare gender differences for continuous variables.

^bAdjusted for accelerometer wear time.

Table 3. Linear multilevel regression coefficients predicting academic achievement score.

	B (SE)	P-Value
Academic achievement scores		
Model 1		
Sedentary time	0.00021 (0.00031)	0.498
Model 2		
Sedentary time	0.00015 (0.00034)	0.659
Model 3		
Sedentary time	−0.00151 (0.00121)	0.455
MVPA	−0.00241 (0.00167)	0.149
Model 4		
Sedentary time	0.00027 (0.00035)	0.441
CRF	0.01617 (0.01124)	0.150
Model 5		
Sedentary time	0.00046 (0.00035)	0.188
Motor coordination	0.00234 (0.00080)	0.003*

MVPA: moderate-to-vigorous physical activity; CRF: cardiorespiratory fitness.

Model 1 – adjusted for accelerometer wear time.

Model 2 – adjusted for accelerometer wear time, age, gender and body mass index.

Model 3 – adjusted for accelerometer wear time, age, gender, body mass index and MVPA.

Model 4 – adjusted for accelerometer wear time, age, gender, body mass index, socio-economic status, mother education level and cardiorespiratory fitness.

Model 5 – adjusted for accelerometer wear time, age, gender, body mass index and motor coordination.

* $P < 0.05$.

In fact, a large part of children's SB out of school is spent in screen time, and it has been demonstrated that media use is negatively associated with executive functions (Lillard & Peterson, 2011), which, in turn, are strongly related to AA (Blair & Diamond, 2008). Furthermore, the intense and exciting sensations induced as a result of media use are incompatible with the concentration required for reading and writing (Sharif et al., 2010; Syvaioja et al., 2013). Additionally, as the hypothesis of time displacement suggests, the time spent in SB may displace time from other activities directly associated with academic performance, such as doing homework, reading or sleeping (Anderson, Huston, Schmitt, Linebarger, & Wright, 2001; Stea, Knutsen, & Torstveit, 2014; Trudeau & Shephard, 2008; Wiecha et al., 2001).

However, this is not a universal finding, as some authors found a positive association between SB and AA (Boot, Blakely, & Simons, 2011; Dye, Green, & Bavelier, 2009; Granic, Lobel, & Engels, 2014; Haapala et al., 2014; Jackson, von Eye, Fitzgerald, Witt, & Zhao, 2011; Spence & Feng, 2010; Willoughby, 2008). Nevertheless, investigations of media use also support that educational TV viewing, video games, interactive websites and multimedia software programmes appear to offer a variety of potential benefits for learning (Schmidt & Vandewater, 2008). These contradictory results may be due to the difference in contexts where SB levels were analysed (Haapala et al., 2014), the age and gender of the participants (Jackson et al., 2011) and the measures of AA used.

The use of objective measurement of sedentary time allows the present study to capture the entire daily amount of this behaviour. However, it is not possible to know the types of SB that children are engaged in. Nevertheless, in our study, children spent, on average, 75.6% of their day in sedentary activity. This finding concurs with other studies that have also found that children spend significant proportions of their waking time, between 50% and 80%, being sedentary (Colley

et al., 2011; Matthews et al., 2008). Indeed, even schools are extremely inactive and sedentary environments (Nettlefold et al., 2011), with European children spending only 5% of their school day engaged in MVPA and 65% in sedentary activities (van Stralen et al., 2014). Given that, currently, the daily lives of children are mostly being spent in SB, it is not surprising that today's children are less active, less fit, have lower levels of motor coordination, are fatter and are less healthy than previous generations (CDC, 2000; Roth et al., 2010). Consequently, they may be at greater risk for present and future health impairments, since the early years are a formative period for proper growth and development (Hinkley, Salmon, Okely, & Trost, 2010; Tremblay et al., 2012), which in turn may also affect their academic attainment.

The negative effects of sedentary lifestyles on children's health and health-related behaviours and outcomes are a source of concern (Healy & Owen, 2010). In a recent review study about the relationship of adolescents' AA and health behaviours, Bradley et al. (2013) concluded that the promotion of academic success in youth susceptible to at-risk health behaviours may reduce the likelihood of them engaging in behaviours that threaten not only their health but also their performance at school. Considering the importance of establishing healthy lifestyles from a young age, actions aiming to address the current crisis of sedentary time should attempt to both increase physical activity levels and decrease SB (Tremblay et al., 2011).

Our results also show that motor coordination was associated with AA; this finding agrees with previous studies (Haapala, 2013; Lopes et al., 2013). It is known that the neuronal structures (cerebellum and the frontal lobe) that are responsible for coordination are also responsible for cognition (Serrien, Ivry, & Swinnen, 2006). However, our results contrast to other studies for MVPA (Trudeau & Shephard, 2008) and for cardiorespiratory fitness (Haapala, 2013) as we did not find associations with AA. Probably because to perform better academically, children may need to attain higher levels of vigorous physical activity (Coe, Pivarnik, Womack, Reeves, & Malina, 2006). Nonetheless and although parents often perceive that sports activities may "displace" time that would normally be spent in educational activities (i.e., doing homework, reading), there is a growing body of research indicating that physical activity has potential biological, psychological and social benefits in regard to AA (Lopes et al., 2013; Trudeau & Shephard, 2009). Intervention studies have also reported that children engaged in more physical activity do not compromise their AA, in spite of the reduction of time spent on "academic subjects" (Trudeau & Shephard, 2008). Indeed, ignoring the latest results of the literature in this field and in an attempt to maximise academic performance, officials have recently proposed a reduction in the amount of time spent on physical education in school curriculum and/or a reduction or the elimination of school recesses, two of the most important and significant daily physical activity opportunities for children (Mota et al., 2005). In fact, the harmful effects of SB may occur as a result of replacing time spent in physical activities; however, few studies have explored this hypothesis (Hamer, Stamatakis, & Steptoe, 2014).

The strengths of this study include the use of objective assessment of both total sedentary time and total physical

activity, as most previous studies have limited their analysis to self-reported leisure time SB and/or physical activity; the inclusion of several potential confounders, for example, motor coordination that was found to be predictor of AA (Lopes et al., 2013); and the use of an objective measure of academic performance. In this study, AA was measured with a standardised test that relied neither on teacher's subjective evaluations nor on grade point averages.

The limitations of this study include its cross-sectional design, and consequently, the results do not indicate causality. The use of accelerometers does not identify physical activity or sedentary time contexts (school or out of school time, nor type of leisure-time sedentary activities).

In conclusion, in this study, objectively measured sedentary time was not associated with AA, after adjusting for potential confounders. Although the study of objectively measured sedentary time and AA is in its early stages and the factors underlying these associations are not fully understood, these initial findings may be promising, and a deeper knowledge about this topic could provide further insight aimed at improving brain health and cognitive function across the human lifespan (Burkhalter & Hillman, 2011). Future studies in this age group are necessary, and should address the analysis of sedentary time patterns and types of SBs in which these children are engaged.

Disclosure statement

No potential conflict of interest was reported by the authors.

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